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RESEARCH MEMORANDUM

FLIGHT PERFORMANCE OF A 2.8 KS 8100 CAJUN SOLID-PROPELLANT ROCKET MOTOR

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January 21, 1957

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

FLIGHT PERFORMANCE OF A 2.8 KS 8100 CAJUN SOLID-PROPELLANT ROCKET MOTOR

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SUMMARY

The performance of a 2.8 KS 8100 Cajun solid-propellant rocket motor has been determined from the free-flight test of a single-stage model which reached a velocity of 5,268 feet per second (Mach number, 4.74). Thrust data from the flight test are compared with data obtained from a ground firing test made by the manufacturer and the two are shown to be in agreement.

INTRODUCTION

The Cajun rocket motor was developed by the Thiokol Chemical Corporation, Elkton Division, under a contract with the National Advisory Committee for Aeronautics specifically for propulsion of pilotless aircraft research models. In order to check the 2.8 KS 8100 Cajun rocket motor operationally and to determine its performance for use in research models, a flight test of the Cajun rocket motor was made. With an average thrust of 8,100 pounds, the model reached a maximum velocity of 5,268 feet per second, at 3.1 seconds after launching.

The flight test was made at the Langley Pilotless Aircraft Research Station at Wallops Island, Va.

SYMBOLS

a_l longitudinal acceleration, ft/sec^2

C_D drag coefficient, $\frac{D}{\frac{1}{2}\rho V^2 A}$

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D drag, lb

g gravitational constant, 32.2 ft/sec^2

M free-stream Mach number

q dynamic pressure, $\frac{1}{2}\rho V^2$

R Reynolds number, $\frac{\rho V x}{\mu}$

A frontal area, sq ft

t time, sec

T thrust, lb

V velocity, ft/sec

W weight, lb

x body length

ρ density of air, slug/cu ft

μ absolute viscosity of air, slug/ft-sec

θ flight-path angle, deg

Subscripts:

B base drag

T total drag

MODEL AND TESTS

Model Configuration

The model consisted of the Cajun solid-fuel rocket motor with a nose fairing attached to the front and a four-fin tail assembly attached around the nozzle. The general configuration of the model is shown in figure 1(a), and pertinent dimensions are given in figure 1(b). The model was a cone cylinder 120.7 inches long weighing 192.37 pounds fully assembled. The 20° total-angle conical nose had a blunted tip with a

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ratio of nose-tip radius to base radius of 0.25, the base radius being 3.375 inches. The $7\frac{1}{2}$-pound nose was constructed of 1020 steel 0.13 inch thick except for the tip which was 0.63 inch thick. The fin assembly consisted of four solid magnesium fins welded to a cylindrical magnesium shroud. The leading edges of the fins were capped with 0.032-inch-thick Inconel sheet attached with rivets. Each fin panel was 0.7986 square foot in area and the four-fin assembly, including the shroud, weighed 18 pounds. The Cajun rocket motor was 103.85 inches in length and weighed 166.9 pounds of which the propellant grain weighed 119 pounds.

Propulsion and Test Technique

The model was launched at an elevation angle of 70°. The single-stage propulsion system was a Cajun rocket motor having a total rated impulse of 24,380 pound-second. Velocity data were obtained by means of a CW Doppler radar set, and altitude and flight-path data were measured by an NACA modified SCR-584 radar tracking set. Atmospheric data and wind conditions were measured by means of a radiosonde launched near the time of flight and tracked by an AN/GMD-1A Rawin set.

The static temperature was 66° F with the temperature of the grain inside the motor chamber estimated to be 72° F.

Data Reduction

The total drag coefficient C_{D_T} was computed from the flight conditions after burnout of the motor as follows:

$$C_{D_T} = \frac{-W\left(a_l + g \sin \theta\right)}{qAg} \tag{1}$$

The longitudinal acceleration a_l was obtained by differentiating the velocity-time curve.

The thrust, at any time t, may be calculated from

$$T = \frac{W\left(a_l + g \sin \theta\right)}{g} + qA\left(C_{D_T} - C_{D_B}\right) \tag{2}$$

A schedule of instantaneous weights based on an actual thrust-time history from a ground test made by the Thiokol Chemical Corporation was used in equation (2) for the weight of the model W, which varied from a loaded weight of 192.37 pounds to a burned out weight of 73.37 pounds.

The drag acting on the model during thrust was assumed to be the total drag less the base drag $C_{D_T} - C_{D_B}$. The base drag was assumed to be zero during thrust. The base drag C_{D_B} during coasting was obtained from reference 1.

RESULTS AND DISCUSSION

Flight Test Data

Figure 2(a) shows time histories of the flight Mach number and velocity. Time histories of altitude and free-stream Reynolds number per foot are shown in figure 2(b). The model accelerated to a velocity of 5,268 feet per second at 3.1 seconds. This velocity corresponded to an airspeed of 5,253 feet per second as a result of a wind correction of 15 feet per second. At this time the free-stream Mach number was 4.74.

Drag

The drag coefficients, based on a frontal area of 0.2485 square foot, are shown in figure 3 plotted against free-stream Mach number. The base drag coefficient based on the three-dimensional theory (reference 1) was subtracted from the flight coast data to obtain the drag coefficient of the model during firing.

Acceleration

The longitudinal acceleration a_l as used in equation (2) is shown in figure 4. The rocket motor performed well under the high acceleration, reaching a maximum acceleration of 77g.

Thrust

The thrust time history computed from equation (2) is shown in figure 5, along with the thrust curve provided by Thiokol Chemical Corporation from a ground firing. Both curves show an average thrust of 8,100 pounds with a maximum thrust of approximately 9,500 pounds. The ground firing test gave a total impulse of 24,380 pound-second over an action time of 3.1 seconds. There was no detrimental effect due to the high acceleration.

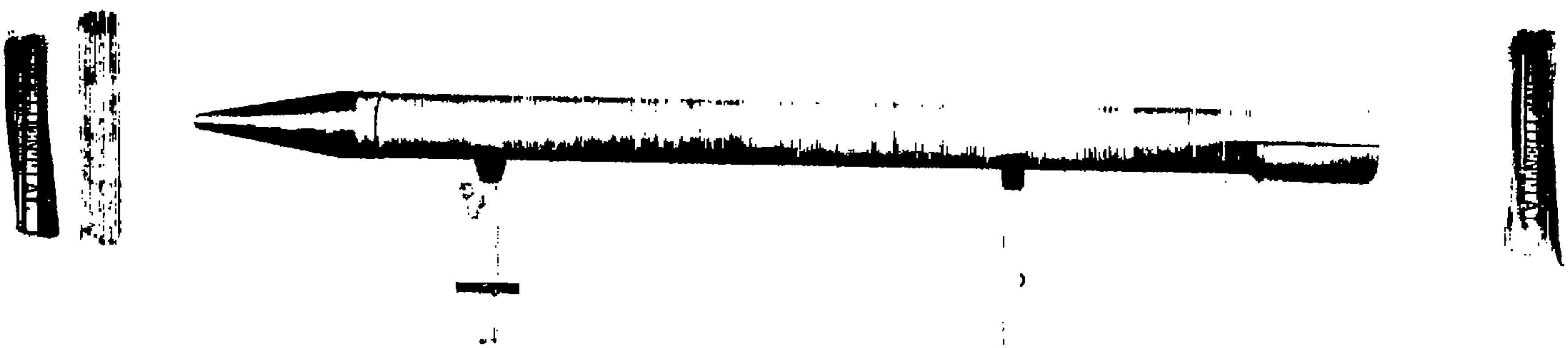
CONCLUDING REMARKS

The performance of a Cajun rocket motor in an actual flight test shows that the Cajun motor with a 7.5-pound nose and an 18-pound fin assembly accelerated to 5,268 feet per second (Mach number, 4.74) at an altitude of approximately 7,000 feet. Its burning time was 3.1 seconds with an average thrust of 8,100 pounds. The rocket motor performed well under the high acceleration of 77g. The thrust-time variation determined during the flight test is in good agreement with the results of ground firing tests.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 15, 1956.

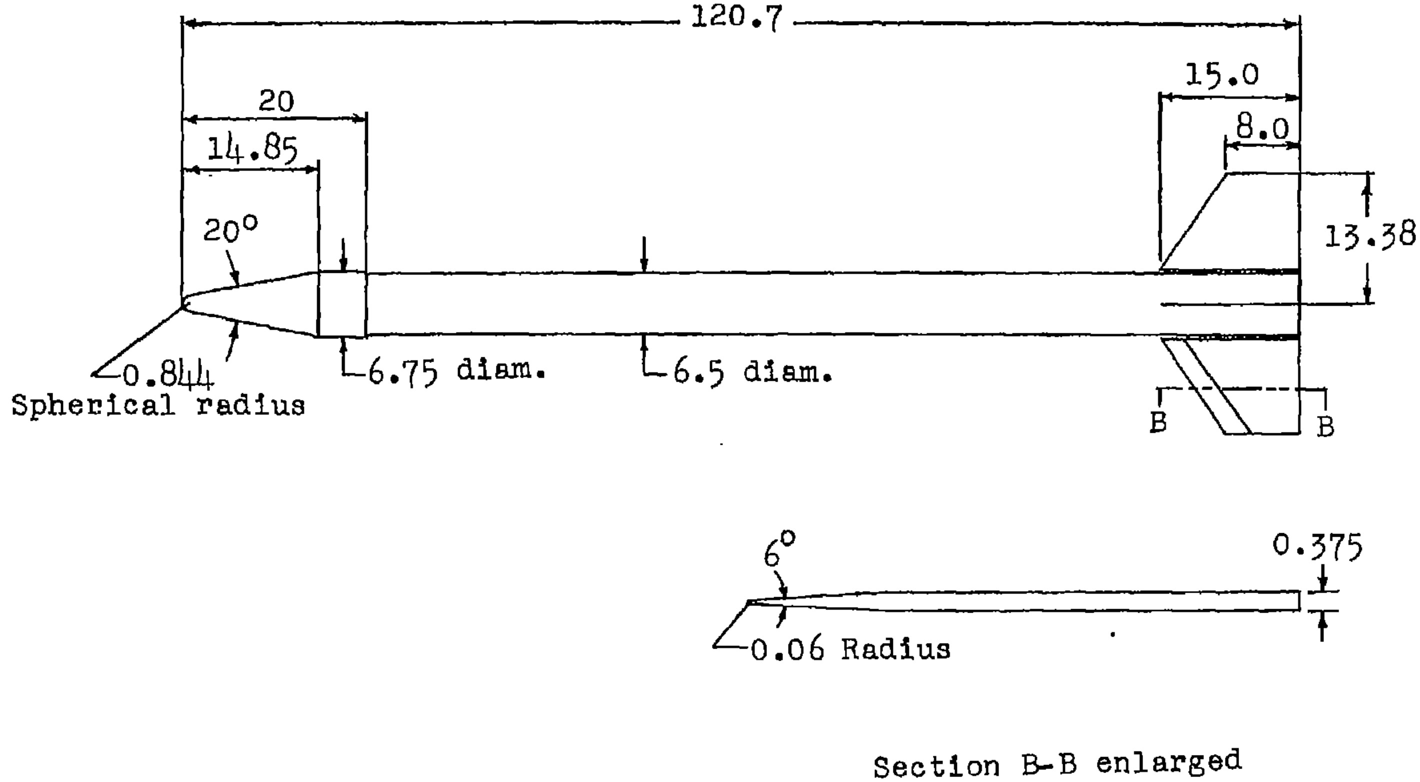
REFERENCE

1. Love, Eugene S.: The Base Pressure At Supersonic Speeds On Two-Dimensional Airfoils and Bodies of Revolution (With and Without Fins) Having Turburlent Boundary Layers. NACA RM L53C02, 1953.



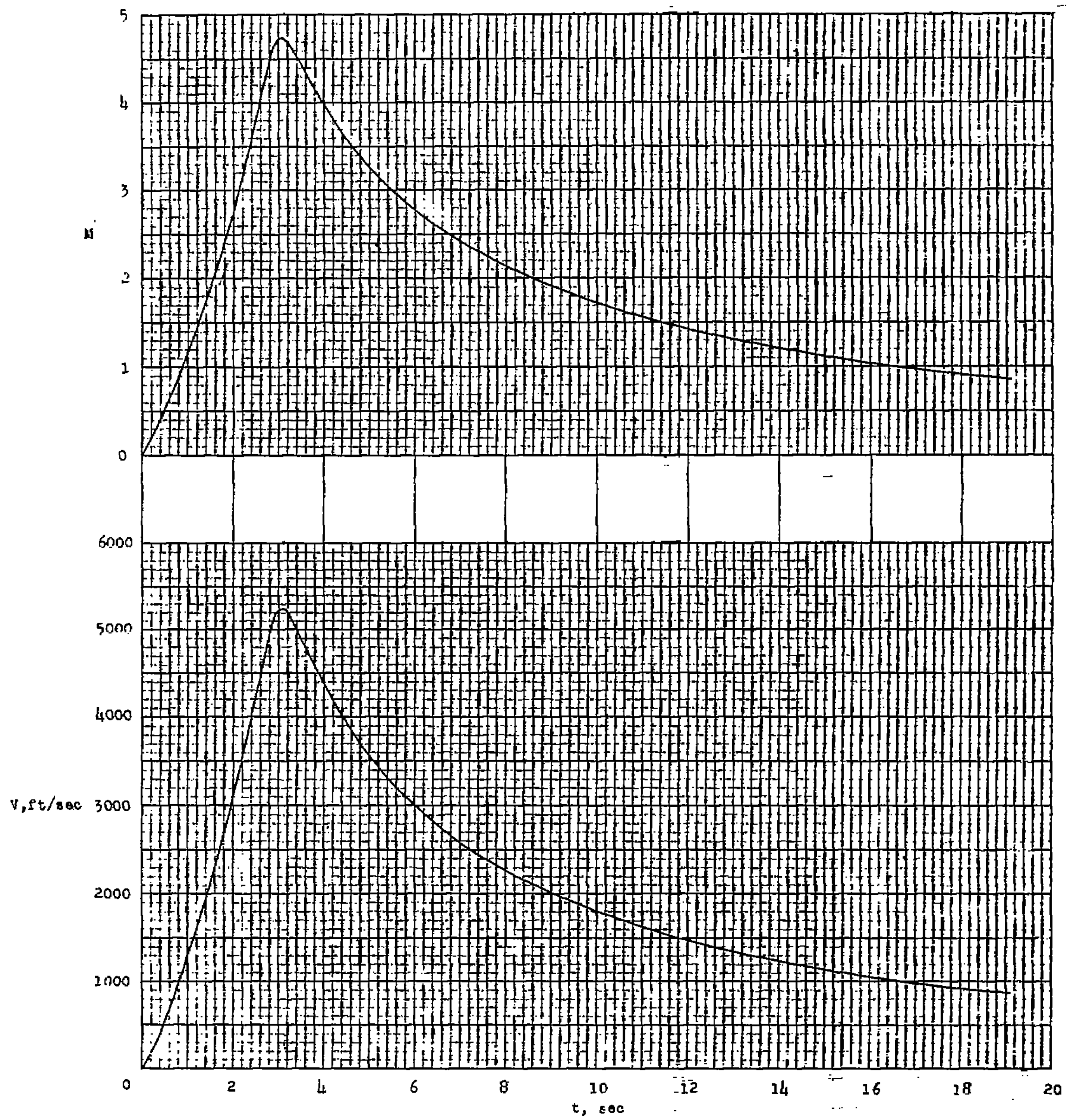
(a) Photograph of model. L-94406

Figure 1.- Test configuration.



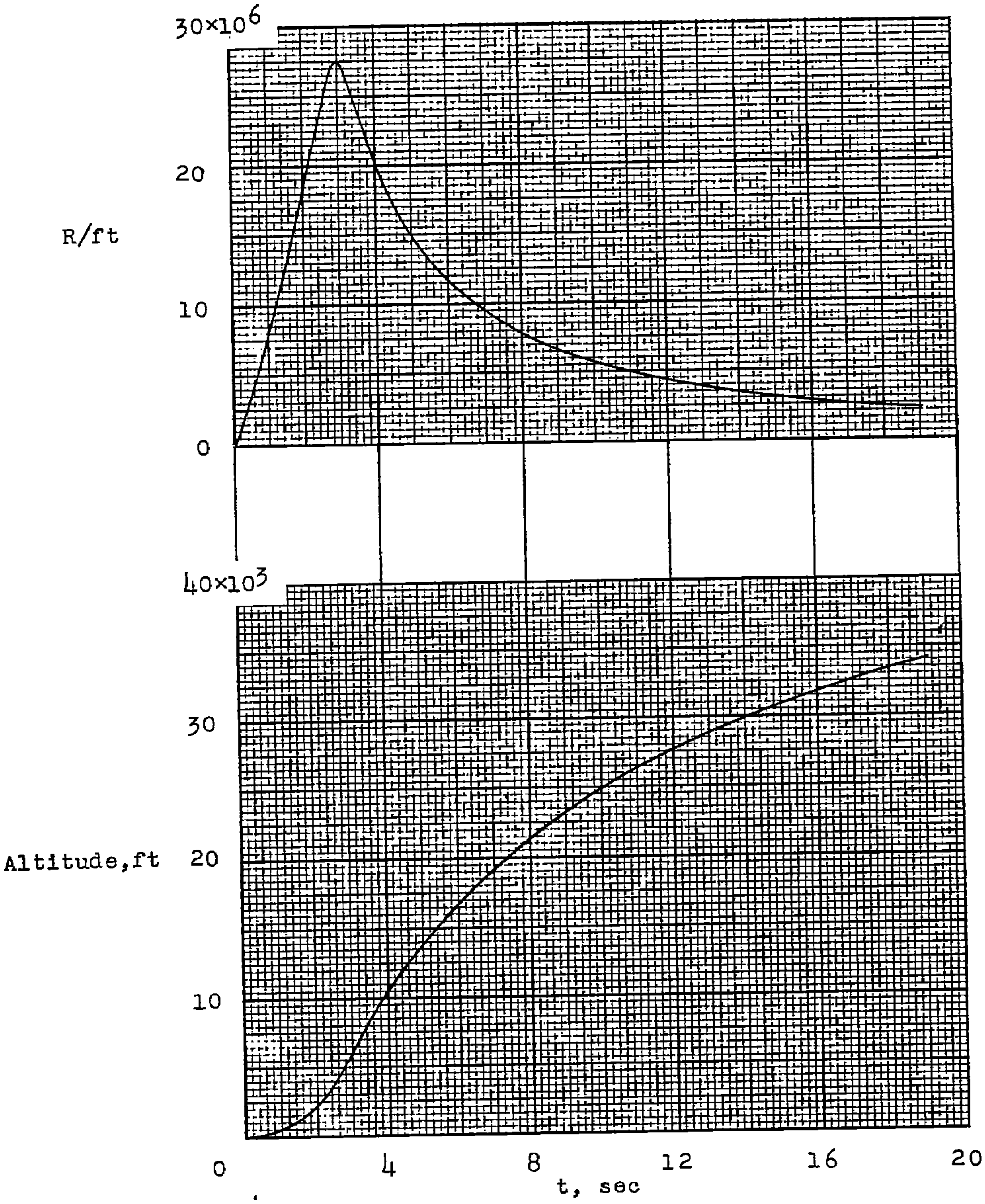
(b) General configuration. Dimensions are in inches.

Figure 1.- Concluded.



(a) Time history of Mach number and velocity.

Figure 2.- Test conditions.



(b) Time history of Reynolds number per foot and altitude.

Figure 2.- Concluded.

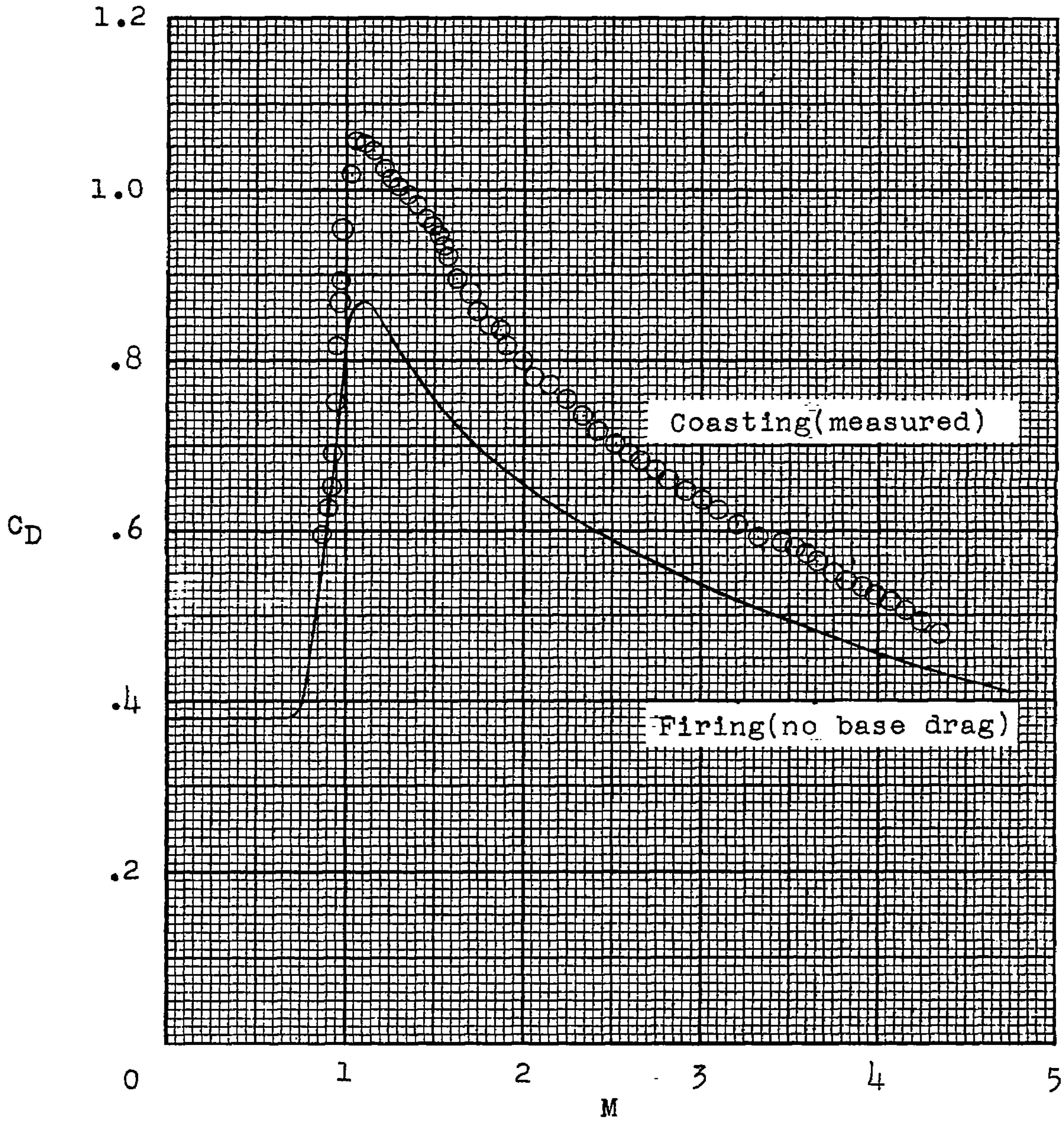


Figure 3.- Variation of drag coefficient with Mach number. A = 0.2485.

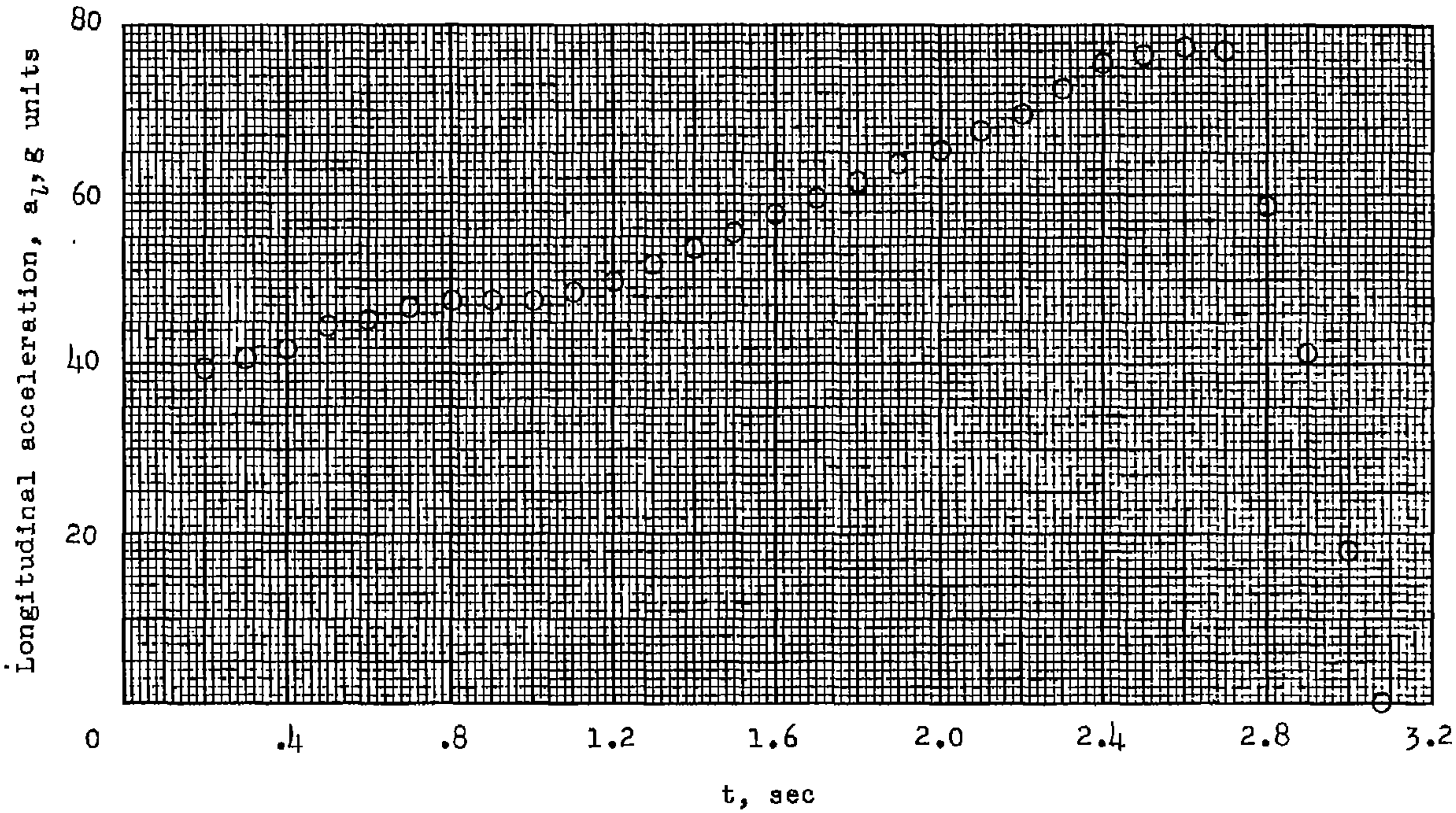


Figure 4.- Longitudinal acceleration during firing against time.

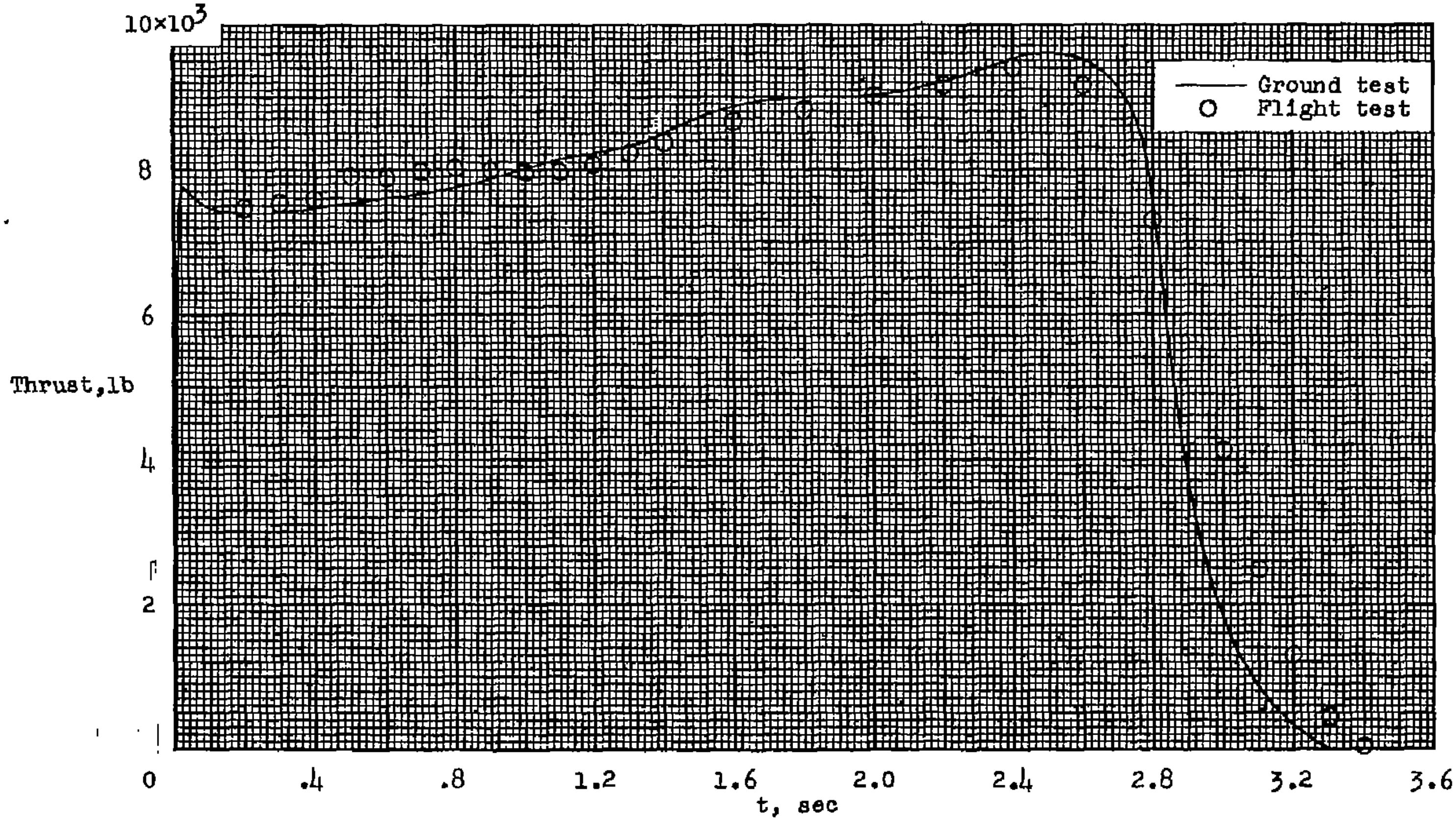


Figure 5.- Thrust time history.